Parallel Wireless 5G Vision

Reimagine Your Network

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Table of Contents

Parallel Wireless 5G Vision

Introduction

As we are approaching 2020, the standards for 5G are being finalized. 5G, the 3GPP version of ITU IMT-2020, is the main and only real contender for the next generation of mobile technology. What is obvious to everyone is that 5G will naturally evolve from 4G and will drive ecosystem innovation to deliver enhanced customer experience while extending 4G network investments.

Varying network maturity in different regions requires a solution that can address older (2G/3G/4G) generation technologies while managing future (5G) networks – what will work for the more advanced market likely won't be a good option for less developed markets.

The defining challenge of the next ten years will be to efficiently deploy and manage networks that are becoming more complex in order to address the challenges of increasing data usage and higher density. The issue with managing these networks is that they are comprised of several different technologies and interfaces.

5G is expected to target new services and business models as shown in figure 1 below.

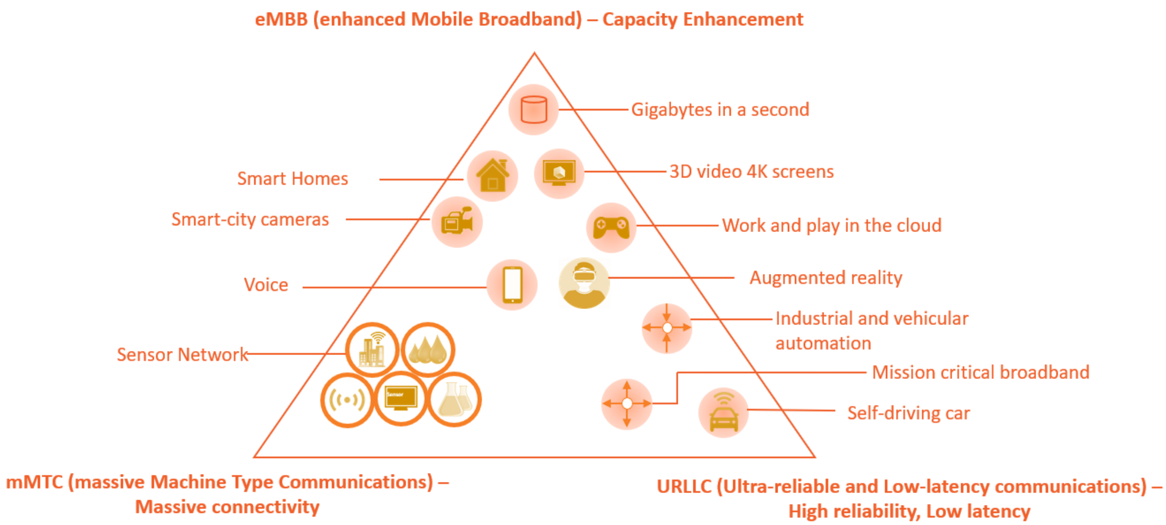

Figure 1: IMT-2020/5G Requirements as defined by ITU-R

The three major service categories defined for 5G are:

- Enhanced Mobile Broadband (eMBB): This is expected to be an evolution of Mobile Broadband that has been constantly evolving and improving since 3G days.
- Massive IoT or Machine Type Communications (mMTC): Machine Type Communications (MTC) is the 3GPP name for M2M technology. With IoT permeating everyday objects and actions, the number of M2M devices are expected to gr ow exponentially. This is the key driver for massive MTC.
- Ultra-Reliable and Low Latency Communications (URLLC): Some services and applications have a very critical requirement about reliability and latency. These have been lumped together as part of URLLC. This does not preclude network offering just Ultra-Reliable (UR) and/or Low Latency Communications (LLC) services.

As per ongoing standards work underway, it is understood that to comply with the services and use case scenarios shown above, 5G comprises a complex set of technical requirements for all elements of a mobile network, not only in the RAN but also in the Core Network. It is expected that standards for all such scenarios will be completed by 2020, as part of Release 16.

However, in order to introduce some of the benefits earlier, delivery of functionality has been split into two phases:

- Phase 1 with focus on eMBB, allowing MNOs to provide higher speeds and services like Fixed Wireless Access. Commercial deployments of this phase are already underway.
- Phase 2 will add support for Massive IoT and URLLC scenarios.

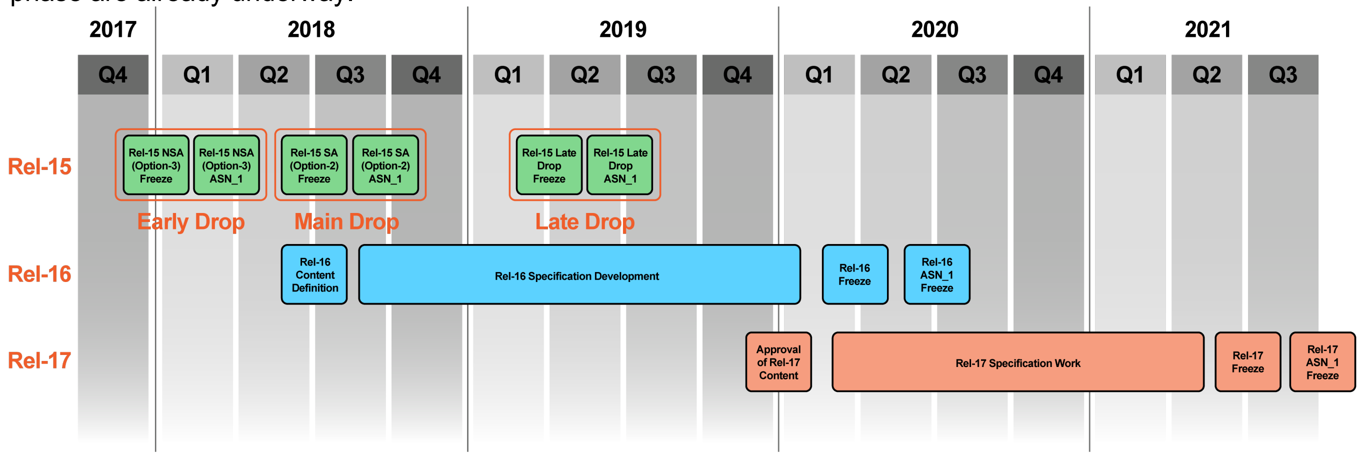

Figure 2: 5G Phase 1 and Phase 2 timelines (Source: 3GPP)

In order to expedite network availability, phase 1 enables MNOs to launch services with new 5G radio (aka NR), with the ability to use either an existing 4G core, or a newly deployed 5G Core. The former is called Non-Standalone Mode (NSA), the latter Standalone Mode (SA).

In addition to the core network, RAN is undergoing a major transformation too. Centralized baseband processing was introduced several years ago to ease installation of wireless base stations in large buildings and on campuses. This was enabled by digital radio interfaces and remote radio heads (RRHs) which allowed the connection between RRHs and digital baseband units (BBUs) to be carried over fiber. The concept has subsequently been generalized to span larger areas involving many radio sites while still using a central BBU. With the increase in deployment footprint, availability of required fronthaul has become a major issue.

5G requirements have compelled various organizations, 3GPP and other standards bodies, to start looking for solutions to address this issue. By distributing protocol stacks between different components (different splits), solution providers focus on addressing the tight requirements for a near perfect fronthaul between RRHs and BBUs.

This whitepaper will look at how Parallel Wireless's cloud-native dynamic architecture addresses various pain points experienced by different service providers. The OpenRAN controller is a highly optimized and versatile software-based solution that addresses many different challenges with network deployment and optimization. In addition, it is the only available solution for mobile operators to utilize different 5G functional splits based on morphology and infrastructure availability.

While for coverage deployment higher splits are more desirable, for capacity in dense urban areas lower splits will be the optimum solution. While higher level splits can utilize less than perfect fronthaul, lower level splits need to utilize near perfect fronthaul. Parallel Wireless's solution allows mobile operators to pick and choose different splits based on the same hardware and network components by using different software implementations. Different protocol layers will reside in different components based on FH availability and morphology. This approach will dramatically reduce the cost of operations and ownership for mobile operators.

5G System (5GS) and 5G Core (5GC)

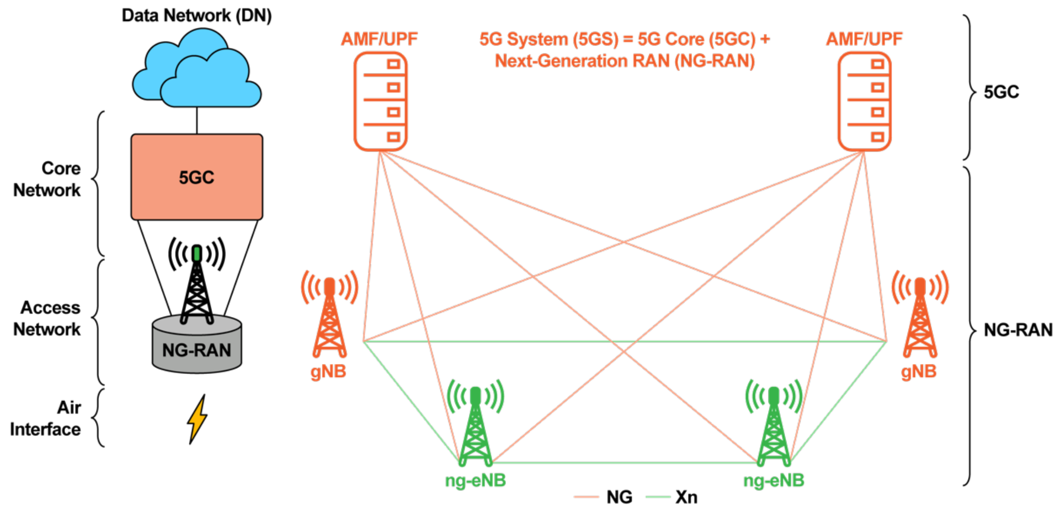

Figure 3: 5G System (5GS), 5G Core (5GC) and Next-Generation RAN (NG-RAN)

The Next Generation Core Network (NGCN) or the 5G Core (5GC) standards are being specified by 3GPP and are expected to be fully ready by 2020 (Release 16). The term 5G has been broadened by 3GPP to mean the 'New Radio' (NR) and anything new in LTE (from 3GPP Release 15 onwards). Collectively they are referred to as Next-Generation RAN (NG-RAN). 5GC and NG-RAN are known as the 5G System (5GS).

The justification for LTE being included as part of 5G is that the Non-Standalone (NSA) architecture that is being submitted to ITU for IMT-2020 includes the LTE network too. At this time, there is no guidance from 3GPP to suggest that someone deploying a Release 15-compliant LTE network cannot claim it to be a 5G network. While some operators have initially tried to misuse the term 5G, it now looks like industry is consistent on how they would market their 5G networks.

In order to expedite network deployment, 5G phase 1 enabled MNOs to launch 5G services quickly using existing 4G EPC (Evolved Packet Core) with new 5G radio (NR). Some operators on the other hand are only looking at launching 5G networks using 5G Core along with the New Radio. The former is called Non-Standalone Mode (NSA), the latter Standalone Mode (SA).

As a result, there will be potentially multiple core options in 5G:

- Standalone (SA)
- Non-standalone (NSA)
- LTE-assisted
- NR-assisted
- EPC-connected
- NGCN connected

These options are summarized in the picture below

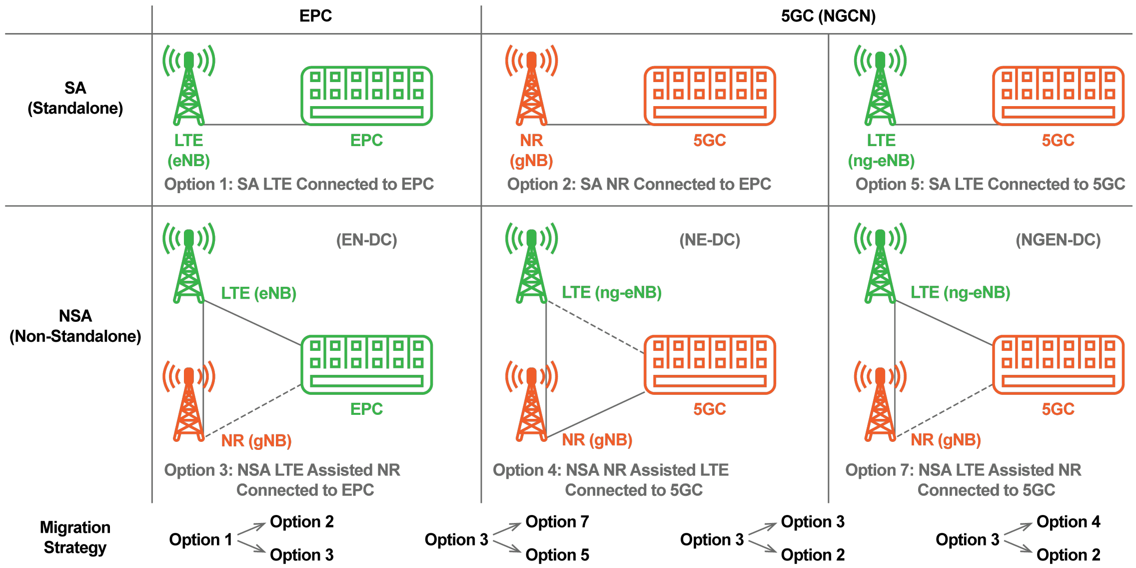

Figure 4: 5G Deployment Options and Migration Strategy

5G NR Radio Access Network

3GPP RAN working groups completed the study on scenarios and requirements for next generation new radio (NR) access technologies as a part of 3GPP Release-15 for 5G. In general, the agreement was that the NR RAN consists of gNodeBs (or gNBs for short), providing the user plane (UP) and control plane (CP) protocol terminations for the radio interfaces toward UEs and core network as shown in figure 5 below.

The gNBs can be connected to each other via Xn interface. The gNBs are ultimately expected to be connected to the 5G core network (5GC) via NG interfaces. Specifically, gNBs will be connected to Access and Mobility Function (AMF) via N2 (NG-C) interface and to User Plane Function (UPF) vis N3 (NG-U) interface.

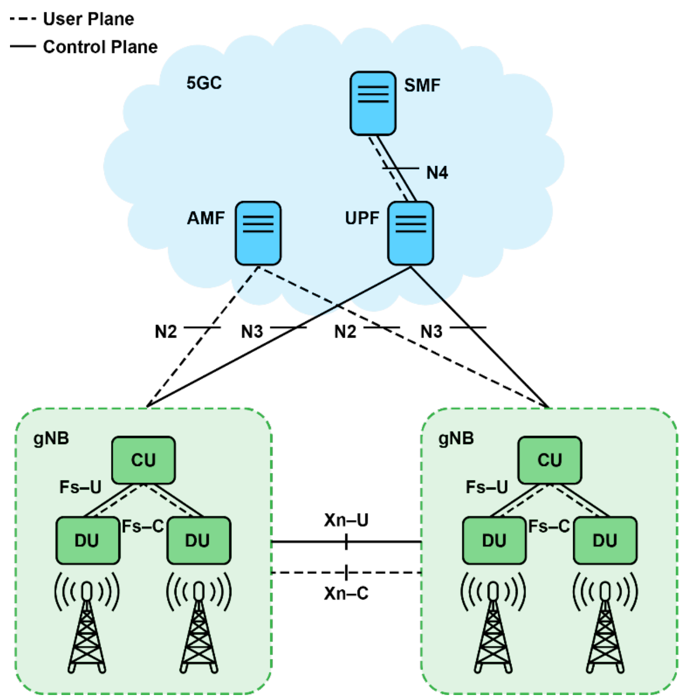

Figure 5: 5G Deployment Options and Migration Strategy

3GPP considered the split concept (DU and CU) from the beginning for 5G. The gNB may consist of a Centralized Unit (CU) and one or more Distributed Units (DUs) connected to the CU via Fs-C and Fs-U interfaces for CP and UP respectively. The split architecture will enable the 5G network to utilize different distribution of protocol stacks between CU and DUs depending on fronthaul availability and network design criteria.

5G Functional Split Motivations

Mobile solutions are expected to address different requirements based on their deployment regions and socio-economic environment. While in Western Europe and North America specific network performance of mobile networks such as higher throughput and lower latency are required, in Africa and other developing parts of the world a completely different set of performance indicators are important; including deployments with less than perfect backhauls and low cost for deployment. Considering these diverse sets of requirements, future mobile networks need to be dynamic enough to address these issues accordingly.

Mobile operators in developed countries continue to face higher data usage rates by subscribers. In order to address this, mobile operators need to spend a lot on new equipment and services which increases CAPEX and OPEX. This has significantly reduced profitability and forced mobile operators to find new ways of expanding the capacity of their networks while remaining profitable. On the other extreme, in developing countries and rural areas of developed countries, mobile operators face the challenge of providing acceptable services while meeting their financial targets considering low average revenue per user (ARPU). This paradigm requires a completely new and dynamic architecture for future mobile networks and particularly 5G.

The future evolution of RAN will be toward dynamic functional splits. While the gateway (aggregator) acts as a mediator between RAN and core network, the functionality of the RAN will be distributed between DUs and CUs as it is defined in 5G (figure 6). In different scenarios, these elements can collapse together and create a single physical entity with different virtual functionalities. The centralized baseband deployment is initially proposed to allow load-balancing between different base stations. Therefore, in most cases DU will be collocated with RRH to conduct all computationally intense processing tasks such as fast Fourier transform/inverse fast Fourier transform (FFT/IFFT) which are not load dependent and exhibit no sharing gains. CU can be separate or collocated with the aggregator depending on fronthaul availability.

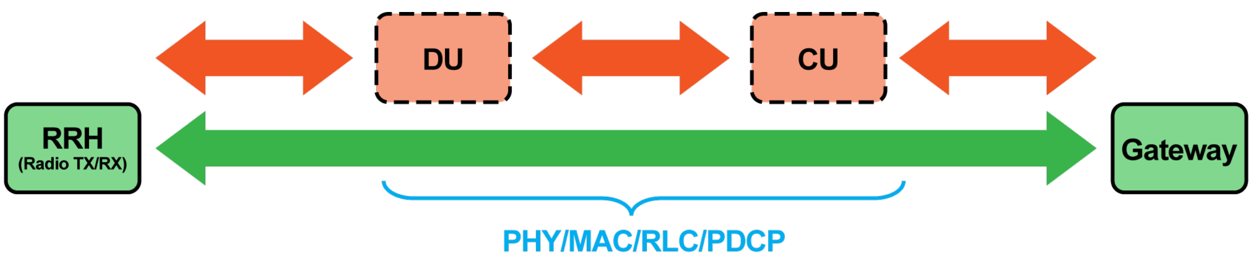

Figure 6: RAN elements

The logical topology of fronthaul will be diversified in the future 5G networks. As mentioned previously, centralized cooperative processing requires an fronthaul network to aggregate (distribute) information from (to) multiple RRHs to a BBU or transport information between BBUs. This will not be an optimal solution to be applied for different deployment scenarios based on different morphologies. Therefore, as a part of 3GPP framework, multiple functional splitting has been proposed to meet these diverse requirements [2]. The existing C-RAN concept (split 8) is an optimal solution for networks with perfect fronthaul. We believe a dynamic functional split between a CU and DUs will be the approach for 5G systems and beyond. While CUs will maintain BBU-like functionalities, DUs will be more than RRH in terms of processing capacities. In case of requirements for more delay-sensitive service in 5G (including but not limited to beamforming and configuration), based on appropriate fronthaul availability, the MAC-PHY split will be the preferred solution. Parallel Wireless believes the future 5G is not about specific split but more about flexibility and the ability to create different splits based on different morphologies and deployment scenarios. Parallel Wireless's 5G RAN visualization will address all these requirements through its OpenRAN software suite as an anchoring point and gateway.

5G Logical Split Options

Figure 7 summarizes all proposed split options by 3GPP as follows [2, 3, 4]:

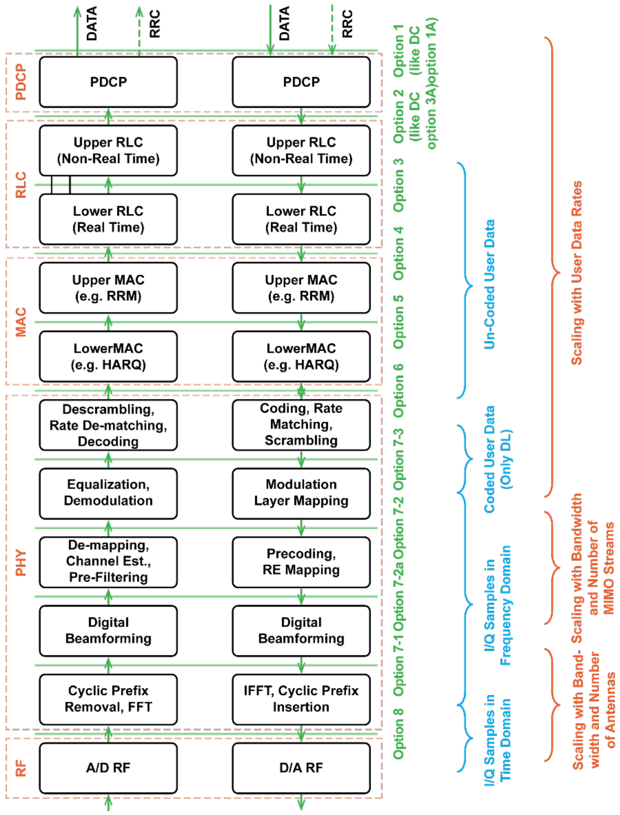

Figure 7: Main Functional Split Options for 5G

- Option 1 (RRC/PDCP split): Same as LTE Rel. 12 DC option 1A
- Option 2 (PDCP/RLC split): Same as LTE Rel 12 DC option 3C for UP (denoted as F1 interface in release 15)
- Option 3 (intra-RLC split): Most of the RLC located in the CU; all ARQ-related functionalities and real time functionalities (like aggregation) located in the RU
- Option 5 (intra-MAC split): High-level scheduling decisions, e.g. ICIC, CoMP, would be performed in the CU Time-critical MAC processing, e.g. HARQ) would be in the DU
- Option 6 (MAC/PHY split): Complete MAC layer located in the CU PHY layer implemented in the CUs. This split requires sub-frame-level timing interactions between CU and DUs since fronthaul delays would affect HARQ timing and scheduling
- Option 7.1: I/FFT and CP insertion/removal performed at DU and rest of PHY located at the CU. I/Q samples in frequency domain are exchanged over the interface. Compared to option 8 only the samples related to occupied sub-carriers need to be exchanged instead of time domain samples reflecting the whole system bandwidth
- Options 7-2 and 7-2a: Pre-coding and digital beamforming; or parts of it, are performed at the DU. In this case, fronthaul requirements scale with number of MIMO layers and not number of antenna ports, as it is the case in option 7.1
- Option 8: legacy C-RAN

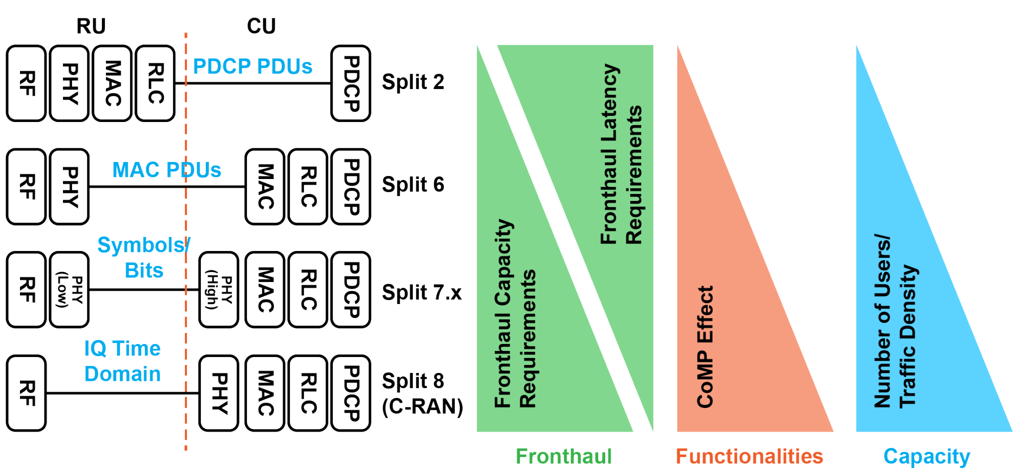

Figure 8: Trade Offs for Different Split Scenarios

Figure 8 shows high level criteria which need to be considered for specific splits during the network design phase. While in dense urban areas with high traffic load and near perfect fronthaul most of the protocol can be located at CU, for rural deployment and less than perfect fronthaul it is logical to push more protocol stack layers to the DU [5].

Parallel Wireless Approach to RAN Splits

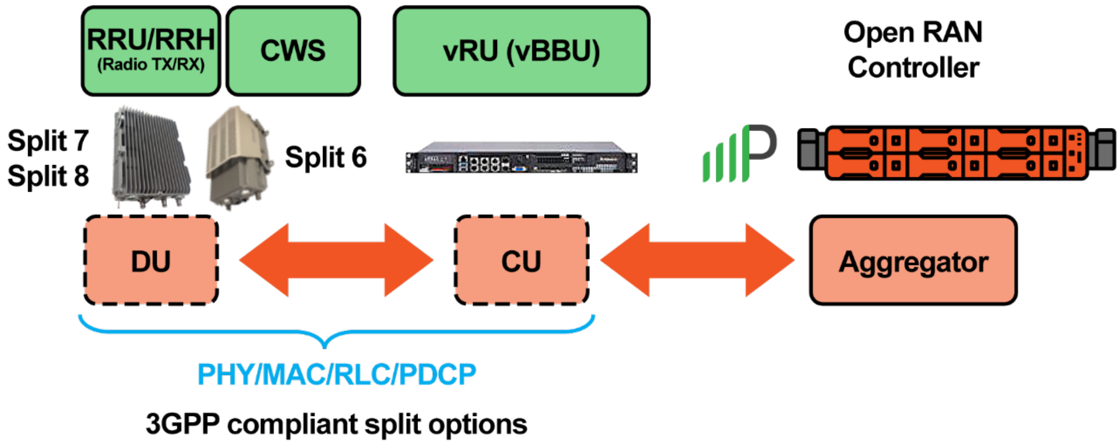

Figure 9: OpenRAN Elements

As described in the previous section, the future evolution of RAN will be toward dynamic functional splits. While a gateway/aggregator acts as a mediator between RAN and core network, the functionality of the RAN will be distributed between DUs and CUs. In different scenarios, these elements can collapse together and create a single physical entity with different virtual functionalities.

The centralized baseband deployment is initially proposed to allow load-balancing between different base stations. Therefore, in most cases DU will be collocated with RRH to conduct all computationally intense processing tasks such as fast Fourier transform/inverse fast Fourier transform (FFT/IFFT) which are not load dependent and exhibit no sharing gains. CU can be separate or collocated with the gateway depending on fronthaul availability.

As discussed in detail in the next section, the Parallel Wireless RRH already provides RRH and DU functionality in one unit. It will be easy to deploy any of the discussed splits due to this availability. We believe lower level splits, 7.x, will be the best approach going forward for deploying future mobile networks in different environments and morphologies. While its requirements for fronthaul is not as restricted as split 8, by utilizing the Virtual Radio Unit (vRU) our solution can support traffic in a dense urban area while maintaining a less than perfect backhaul to connect this local vRU to the OpenRAN software suite.

Also, for rural areas where there is no reliable and high capacity fronthaul availability, the local vRU connection to RRH will utilize a close to perfect fronthaul since they are in close proximity and utilize less than perfect backhauls (e.g. satellite links) to connect the vRU (virtualized BBU/vBBU) to the OpenRAN Software Suite that acts as a vCU, orchestrator and aggregator. All these scenarios will be discussed in detail in the following sections

Parallel Wireless Open RAN Software Suite

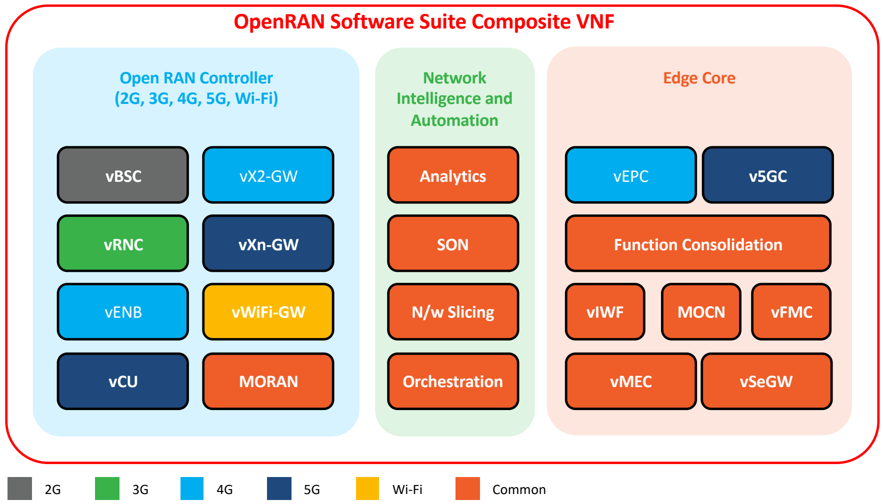

Figure 10: 5G Deployment Options and Migration Strategy

OpenRAN Software Suite is a key element of the Parallel Wireless solution. It encompasses many different controllers, gateways, network intelligence and automation functions and edge core functions. The OpenRAN Software Suite is a fully virtualized, ETSI NFVI-compliant, cloud-native solution that can be deployed on Intel x86-based COTS Data Center infrastructure. Open RAN is enabled through the complete decoupling of hardware and software functionality. This functional separation enables the Open RAN Software Suite to support all the different protocol splits between DUs and CUs based on available backhaul/fronthaul options. Given the breadth of functionality supported by OpenRAN software suite, its sizing is dependent on Call Model details, local and geo-redundancy and data center needs.

Different RAN element functionalities consolidate on the platform, reducing complexity and making overall network maintenance simpler and less resource intensive.

The OpenRAN Software Suite will play a key role in a Service Provider's network to simplify the deployment of 5G and the 5G migration strategy.

The following key functionality is foreseen for the OpenRAN Software Suite with the 5G network:

- It will provide advanced RAN functions, thereby simplifying LTE & NR deployments
    - This includes centralization of RAN functionality to help faster scalability
    - SON will allow for faster deployment while managing interference between different nodes
- It already abstracts core functionality for EPC and will abstract functionality for the 5GC thereby providing distributed core functionality.
    - This will help keep latency down which is a must for URLLC
    - It will also simplify 5G deployment options for operators
- It will seamlessly work with all deployment options for 5G

At a high level it consists of OpenRAN Controller, Network Intelligence & Automation and Edge Core.

OpenRAN Controller: Responsible for radio connection management, mobility management, QoS management, edge services, and interference management for the end user experience. Different RAN element functionalities consolidate on this software platform, reducing complexity and making overall network maintenance simpler and less resource intensive. Currently released OpenRAN controller module virtualizes vBSC/2G gateway, 3G gateway/vRNC, 4G gateway/X2 gateway, Wi-Fi gateway. The fully virtualized and scalable controller functionality supports E2 interface and works with multi-vendor RAN. As a result, it helps create a multivendor, open ecosystem of interoperable components for the various RAN elements and vendors.

Network Intelligence & Automation: The OpenRAN Software Suite provides complete RAN orchestration including self-configuration, self-optimization, and self-healing. All new radio units are self-configured, thereby reducing the need for manual intervention. The self-optimization is responsible for necessary optimization related tasks across different RANs, utilizing available RAN data from the Analytics module. The predictive approach utilized by the Parallel Wireless platform, in contrast to the legacy reactive optimization approach, improves user experience and increases network resource utilization.

Edge Core: This contains the vEPC today and will contain v5GC in future. The function consolidation along with the Inter-working function vIWF allows different network architecture options based on configuration files. MOCN based network sharing is supported for all generations of mobile technology. vMEC supports Multi-Access Edge Computing while Security is enabled by vSeGW

vRU

Based on Intel-based COTS hardware, this component is a virtual BBU (vBBU) and provides High-PHY, MAC, RLC and PDCP functionality in a central fashion. It communicates to a cluster of RRHs (which contains RF and lower PHY) and supports multiple carriers based on the RRH cluster's load. The interface between vRU and RRHs is based on Ethernet-based eCPRI.

RRH

The Parallel Wireless solution utilizes standard off the shelf RRHs from different OEMs. Because of our open software-based solution most commercially available RRHs can be integrated into our solution with minimum integration effort, reducing the overall cost of ownership for mobile operators.

OpenRAN Software Suite as 5G Core Enabler

The Parallel Wireless OpenRAN Software Suite is flexible enough to support **all** possible 5G architecture options, allowing interworking with EPC & 5GC when available. As a result, OpenRAN Software Suite delivers investment protection.

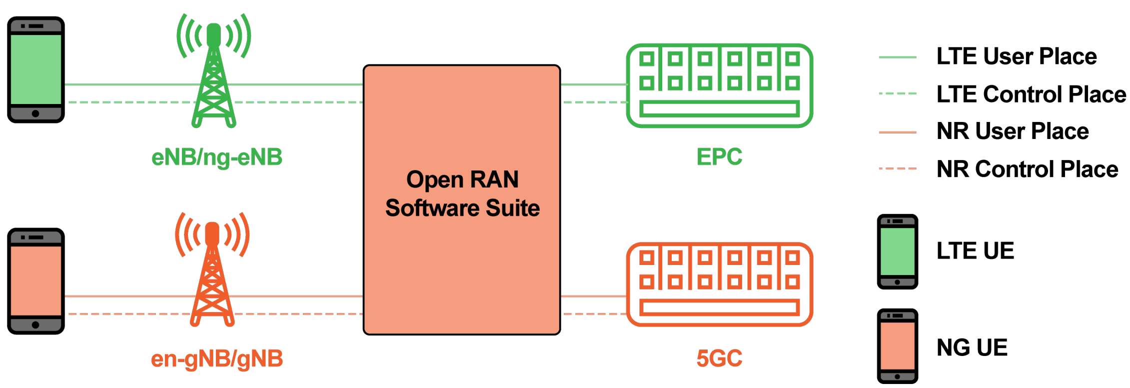

Figure 11: Parallel Wireless Interface Detail for 4G and 5G Core interworking

In addition, the OpenRAN Software Suite abstracts core functionality for EPC & 5GC thereby providing distributed core functionality.

This approach:

- helps keep latency down, which is a must for URLLC
- simplifies 5G deployment options for operators

As a result, the OpenRAN Software Suite works seamlessly for all deployment options described above for 5G, allowing the service provider to gracefully migrate to 5G on the radio and core side.

The OpenRAN Software Suite works with any eNB and with any gNB on the radio side, and on the core side with EPC and 5GC. There is no need to add any additional functionality, 5G readiness is built into the Software Suite. This implies that eNB would evolve in the future to work seamlessly with 5GC. The OpenRAN Software

Suite ensures interoperability between different vendors thereby making it easier for SPs to deploy and operate multi-vendor networks.

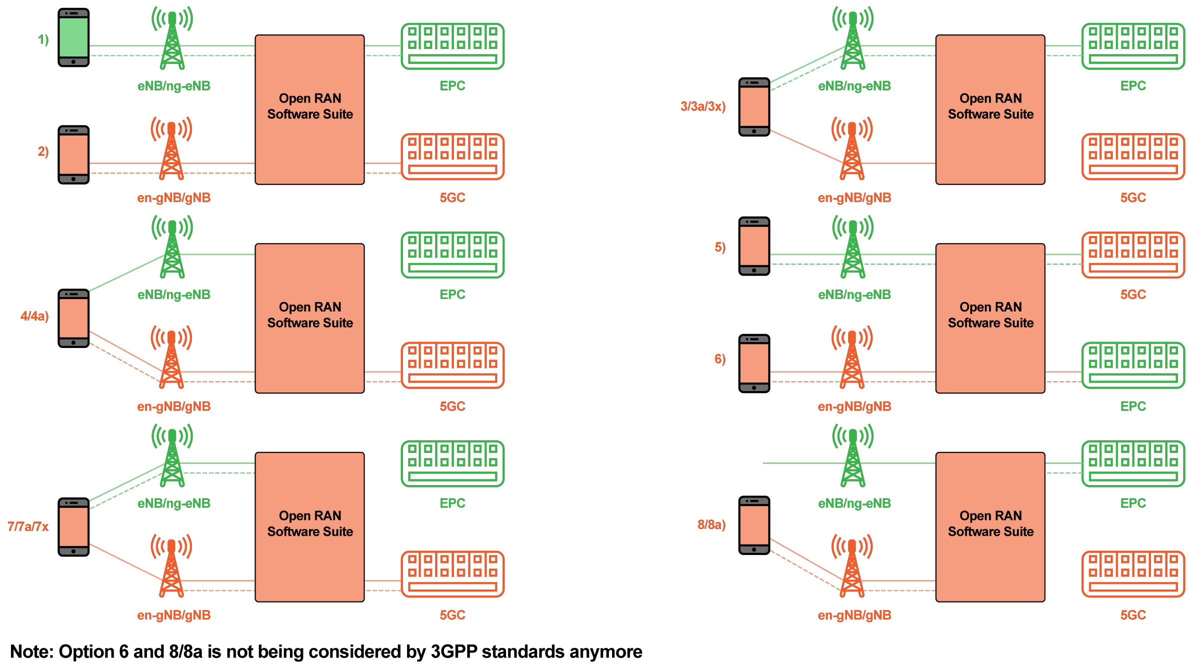

Figure 12: Different 5G Architecture with Open RAN Software Suite

The picture above explains how the OpenRAN Software Suite is expected to support all different 5G deployment options.

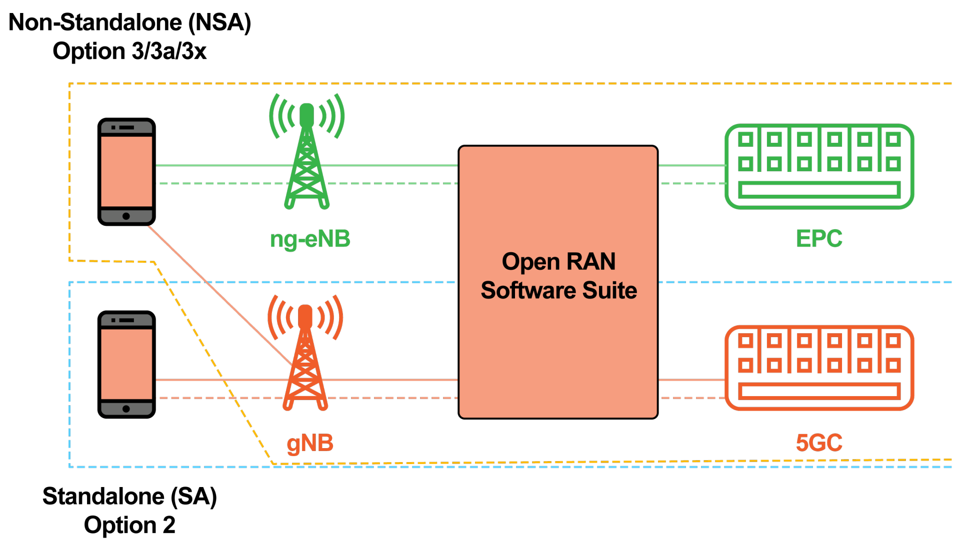

Figure 13: Parallel Wireless High-Level Interworking with 4G and 5G Cores

In addition, figure 13 shows how the two most popular architectures work with the OpenRAN Software Suite. In addition to being able to handle 2G, 3G and 4G RAN and Core functionality, the Software Suite would be able to support multiple 5G network architecture deployment options simultaneously. Each gNodeB can be configured to work as an en-gNB for NSA Option 3/3a/3x or as gNB for SA Option 2. Intelligent algorithms in the software platform can handle routing of signalling and data from each eNB/gNB to the required EPC/5GC. The intelligent algorithms are also able to provide slicing like functionality to legacy 2G/3G networks as well as 4G.

End-to-end Network Slicing

In order to support the different type of services, the network resources, all the way from the RAN to the Internet Access, will require the ability to have End-to-End 'slices', each of them with their own performance characteristics, isolated from the other slices. Each slice has a requirement for a different QoS, security considerations, latency characteristics, Inline Services, etc. For example, the network characteristics for a Best Effort IoT slice will differ significantly from a high-end Enterprise slice (think throughput, latency, always-on vs intermittent connection, data volume, voice vs data-only)

The OpenRAN Software Suite plays a central role in orchestrating the slicing functionality in 4G and, in future, 5G networks.

The network slicing functionality contains access network slices, core network slices and the selection function in the OpenRAN Software Suite that connects these slices into a complete network slice comprised of both the access network and the core network. The selection function routes communications to an appropriate CN slice that is tailored to provide specific services. The criteria of defining the access slices and CN slices include the need to meet different service/applications requirements and to meet different communication requirements.

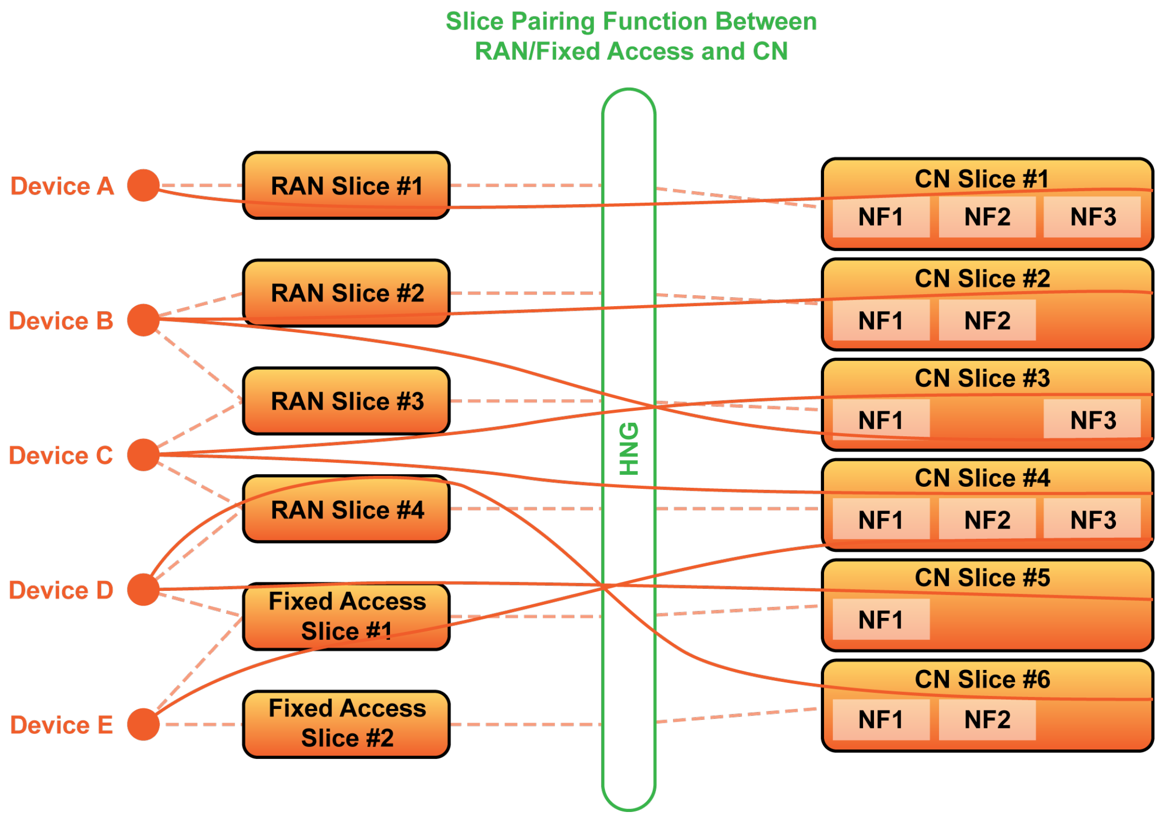

Figure 14: High-level Network Slicing Architecture

Each core network slice is built from a set of network functions (NFs). An important factor in slicing is that some NFs can be used across multiple slices, while other NFs are tailored to a specific slice. Slicing helps support new use cases including private networks and will be a source of new revenue for the SPs.

Signaling Reduction

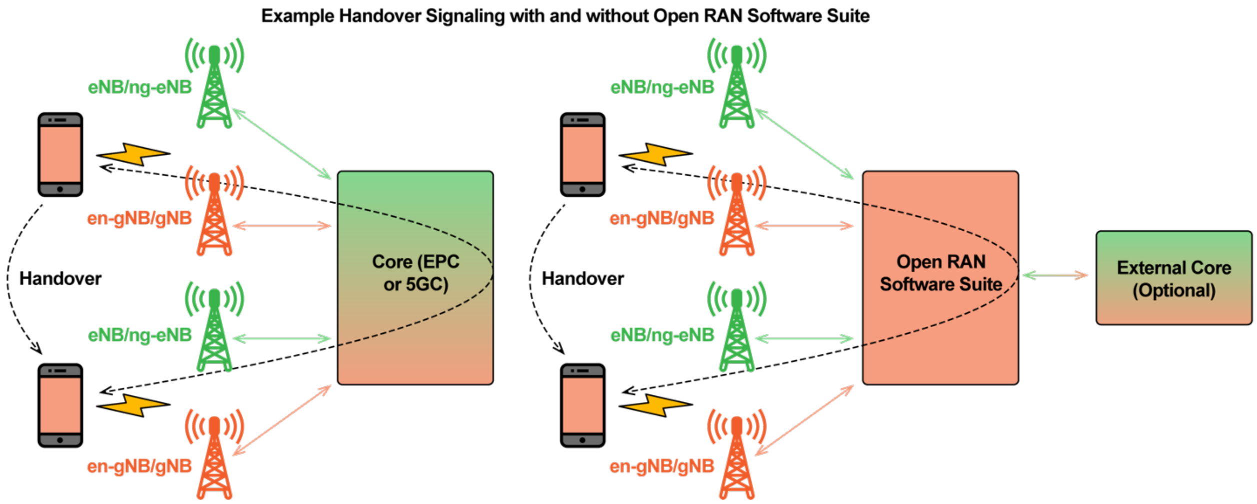

Figure 15: Signaling reduction comparison, with and without the Open RAN Software Suite

The OpenRAN Software Suite allows many different types of optimization in the network by absorbing various signaling traffic from the core. This reduces the load on the core as functionality like paging, handovers, etc., are now being handled in the OpenRAN Software Suite rather than the core.

Signaling reduction in the core allows operators to modify various logical groupings of the number of cells in the Tracking Areas (TAs). Increase in Tracking Area size leads to the UEs reducing the number of signaling updates, thereby saving power consumption.

From a user point of view, signaling reduction may enable faster completion of certain procedures, subject to the location of the OpenRAN Software Suite in the Service Provider's network.

SON

With increasing network complexity, it is even more important to be able to deploy in a quick and simple way. Self-Organizing Networks have helped SPs reduce their CAPEX through various self-configuration features and OPEX through self-optimization features. With 5G complexity being far more than previous generations, SON will play an even more important role in 5G Networks.

Parallel Wireless's Real-Time Hybrid SON solution works with any-G network and Wi-Fi to optimize the end-user experience. It is the only Hybrid-SON solution which can be integrated with distributed third-party nodes and SON solutions.

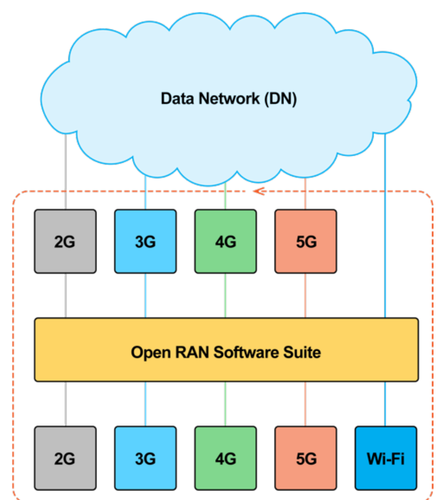

Figure 16: Scope of Parallel Wireless SON

Parallel Wireless Dynamic Function Splitting

Parallel Wireless's existing 3G/4G solution is based on the OpenRAN Software Suite as the gateway between operators' core networks (aggregator) and RRH/vBBUs. The innovative Parallel Wireless solution provides an easy migration path toward 5G while reducing the impact of less than perfect fronthaul in system performance. From the core network's perspective, the OpenRAN Software Suite will act as a single eNodeB (E-UTRAN) and act as the aggregator. CWSs are compact eNodeBs including RRH and processing unit (see figure 17 below).

In all deployed scenarios, a less than perfect backhaul/fronthaul between OpenRAN Software Suite and RRU provides connectivity while maintaining required QoS.

Below we highlight some of the splits (0 and 7) that we see more widely deployed globally.

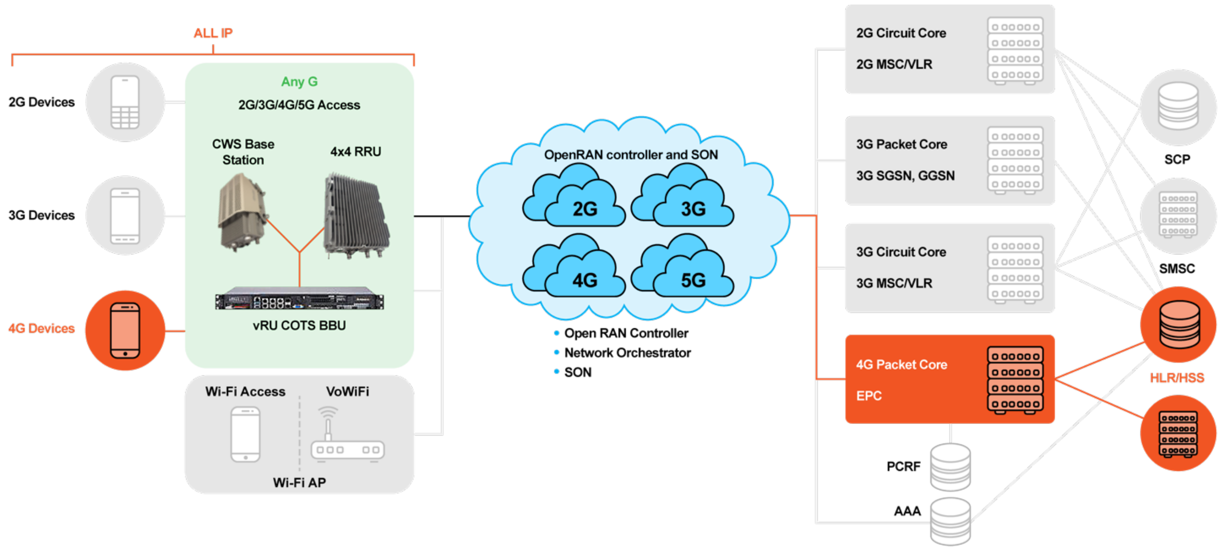

Figure 17: Parallel Wireless 3G/4G Deployment

Parallel Wireless Split 0

For 3G deployments, HNG concentrates all NodeBs to provide single connectivity to Packet Switched (PS) and Circuit Switched (CS) core networks through standard Iu-cs and Iu-ps. As mentioned before, from the core network's perspective, there is one NodeB deployed in the network. Also, HNG will act as a Virtual RNC (vRNC) and aggregate all CWSs as a single NodeB. Using HNG as an aggregation point toward the core network will reduce network-related delays for services like Circuit Switched Fall Back (CSFB) while users are connected to the LTE network and need to go back to the 3G or 2G network for voice (circuit switched) services.

For LTE deployments, HNG concentrates all eNodeBs to provide a single S1-U connection to S-GW for data traffic and a single S1-MME connection to MME for all signaling and control-related traffic. In this case, HNG will act as an aggregator of S1 signaling toward S-GW and MME. This will reduce all handover and paging related signaling and control messages toward the core network (EPC). Parallel Wireless's existing deployments are based on a concentrated RRH/DU/CU at the CWS, while HNG acts as the aggregator.

Advantages and Disadvantages

Pros: This architecture works with low throughput and very high latency backhauls and could be the best solution for remote rural deployment with insufficient infrastructure.

Cons: In case of high traffic load, there may be need for adding vRU.

Parallel Wireless Split 7.2

Architecture and Components

Parallel Wireless recommends option 7.2 split of 3GPP for the case when high throughput and low latency fronthaul is available between vRU and the RRH (see figure 18 below). This is a very efficient and practical PHY split, considering IFFT/FFT are not load dependent and add no sharing gain by accommodating it in the CU. RRH, vRU and OpenRAN software suite products are naturally equipped to support Split 7.2 as discussed.

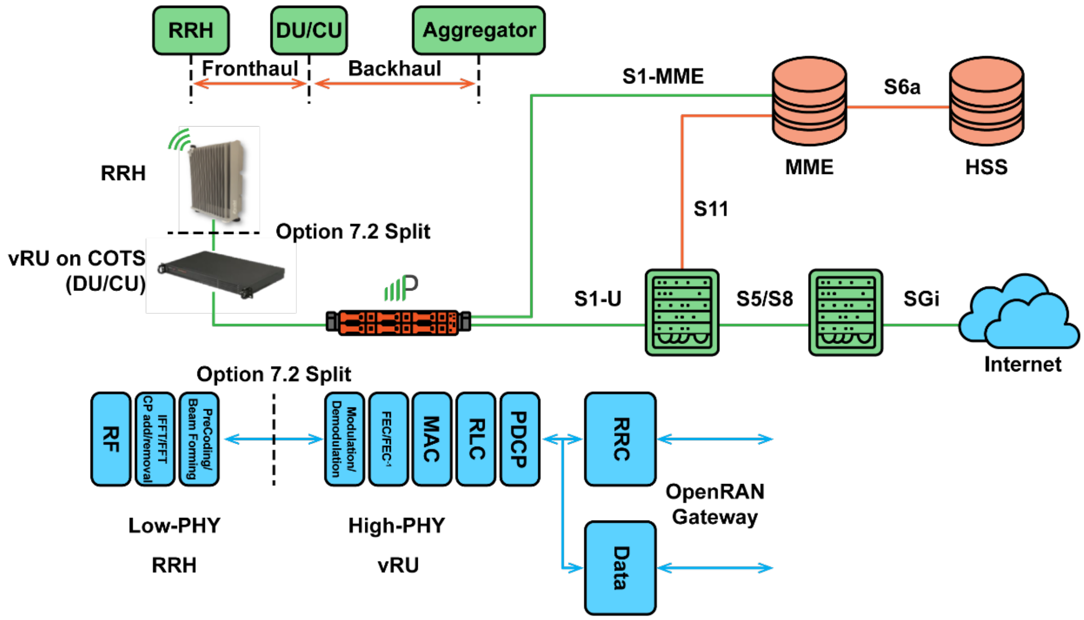

Figure 18: Parallel Wireless Deployment based on Split 7.2

Considering IFFT/FFT and CP addition/removal, the only parts of the overall protocol stack which are not load dependent (located in the DU for split 7.1), this split can be utilized for extreme load balancing scenarios. For morphologies and geographical areas with very non-uniform peak loads, this split can exhibit maximum sharing gain.

Advantages and Disadvantages

Pros: A good solution for dense urban areas. Considering collocation of lower PHY with RRH, IFFT/FFT, precoding and beamforming functionalities that are not load related will be handled remotely.

Cons: Close to perfect fronthaul with latencies below 250 microseconds is required.

Summary

The Parallel Wireless OpenRAN Software Suite enables a 5G-ready architecture which is available to be deployed today. The software-based solution removes deployment and economic constraints by being easy to install and requires minimum on-going maintenance which reduces OPEX. By putting software at the heart of the network, operators can unify all generations of connectivity under the same umbrella and eliminate the need to spend millions of dollars on new equipment and infrastructure upgrades. This approach can help SPs unify their cellular network infrastructure to deliver quality end-user experiences for all coverage or capacity use cases: low density/high density, indoors or public safety 4G/LTE. This is all made possible by virtualization, abstraction, and automation to empower them to be profitable despite margin pressure for 2G/3G/4G and 5G. Operators that take this approach will be in a strong position to win the race for early 5G commercialization. Those that don't, will struggle to survive.

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